

- magnetic resonance signals are acquired,
- the position of a measuring site is measured, and
- the temperature at the measuring site is derived from the magnetic resonance signals.

Because the position of the measuring site is separately measured, the effect of the frequency shift of the magnetic resonance signals (the temperature dependent chemical shift), caused by the temperature variation, can be separated from the frequency encoding of the spatial positions whereto the magnetic resonance signals relate. It is notably possible to derive the local temperature at the exact position of the measuring site from the magnetic resonance signals. The effect of motion of and/or in the object to be imaged, i.e. the patient to be examined, is notably reduced.

Preferably, a set of reference magnetic resonance signals is acquired at a predetermined reference temperature. When the local temperature within the body of the patient to be examined is derived by means of the method according to the invention, the reference temperature is, for example the body temperature of the patient to be examined. Subsequently, the temperature is locally increased and a set of reference magnetic resonance signals is acquired at the increased temperature. Because the position of the measuring site has been separately measured, the temperature dependent chemical shift can be derived from the frequency shift of the measuring magnetic resonance signals relative to the reference magnetic resonance signals, so that the local temperature can be determined at the measuring site. Because the position of the measuring site has been separately measured, the accuracy of the determination of the temperature will hardly be affected when motion of and/or in the patient to be examined occurs between the acquisition of the reference magnetic resonance signals and the measuring magnetic resonance signals. Furthermore, the position of the measuring site at which the local temperature increase is measured is particularly reliable and notably is hardly affected by motions of and/or in the patient to be examined.

Further advantages are achieved by deriving the temperature distribution in the object to be examined on the basis of the measuring magnetic resonance signals, the reference magnetic resonance signals and the position of the measuring site determined. Preferably, this temperature distribution is reproduced as a thermal image. Brightness or color values represent the local temperature in such a thermal image. Furthermore, such a thermal image also contains image information concerning the anatomy of the patient. This image information is acquired by means of magnetic resonance imaging methods which are known per se. Such a temperature distribution constitutes a useful technical aid notably for performing thermal treatment on the body of the patient. Such thermal treatments concern,

for example (laser) ablation of tissue. For example, laser radiation is then used to destroy diseased tissue by local heating. The diseased tissue in the desired region can be readily locally thermally treated on the basis of the temperature distribution reproduced in the thermal image.

5 It has been found that a microcoil is particularly suitable for determining the position of the measuring site. The microcoil is introduced into the body of the patient. The microcoil receives magnetic resonance signals practically exclusively from the immediate vicinity of the microcoil. The magnetic resonance signals received by the microcoil thus accurately represent the current position of the microcoil. The location where the microcoil is
10 situated thus constitutes the measuring site. Microcoils for interventional e.g. endocavitary applications are, for example, smaller than approximately 1 cm. Generally speaking, microcoils having dimensions of between 0.5 mm and 3 mm are used, but even smaller microcoils, being smaller than 1 mm or even as small as approximately 0.1 mm, are also used to determine the position of the measuring site particularly accurately. The microcoil is
15 preferably used in conjunction with an energy-dissipating element. Such an energy-dissipating element locally deposits energy, for example in the form of laser radiation, in the tissue so as to increase the local temperature. The microcoil is preferably arranged near the energy-dissipating element. Furthermore, the microcoil is advantageously used in combination with a temperature sensor. Use is preferably made of a temperature sensor in the
20 form of a fiber thermometer. Such a fiber thermometer has hardly any disturbing effect on the magnetic resonance signals. Preferably, the temperature sensor is arranged in the immediate vicinity of the microcoil. This enables separate measurement of the temperature in the direct vicinity of the microcoil. The temperature distribution relative to the temperature measured at the measuring site can be derived on the basis of the position of the measuring site as
25 determined by the microcoil and the temperature at the measuring site as determined by the temperature sensor.

The invention also relates to a magnetic resonance imaging system. The magnetic resonance imaging system according to the invention is arranged to determine the position of the measuring site. Preferably, the magnetic resonance imaging system according
30 to the invention is provided with the microcoil. Using the microcoil, magnetic resonance signals representing the position of the measuring site are acquired at the area of the measuring site or in the immediate vicinity of the measuring site. Such a microcoil enables measurement of the position of the measuring site with an accuracy of less than 1 mm, for example 0.1 mm. This accuracy is dependent inter alia on the accuracy of measurement of

the temperature and the phase of the position magnetic resonance signals. It is also advantageous to use a plurality of microcoils, for example two or three microcoils. When two microcoils are used, the position and the direction of the line through the microcoils can be measured; when three microcoils are used (not in one line), the position and the orientation of the plane through the three microcoils can be measured. It is also possible to use an even larger number of microcoils in order to measure deformations in the anatomy of the patient. The magnetic resonance image can be corrected for the measured deformation by image processing on the basis of the measured deformations.

The invention also relates to a computer program. The computer program according to the invention contains instructions for the acquisition of magnetic resonance signals, for the determination of the position of the measuring site, and for the reconstruction of the magnetic resonance image from the magnetic resonance signals on the basis of the position of the measuring site determined. The magnetic resonance imaging system includes a computer for executing the various functions of the magnetic resonance imaging system. When the computer program according to the invention is loaded into the computer of the magnetic resonance imaging system, the method according to the invention can be carried out by means of the magnetic resonance imaging system.

These and other aspects of the invention are apparent from and will be elucidated, by way of non-limitative example, with reference to the embodiment described hereinafter and the accompanying drawing; therein:

Fig. 1 shows diagrammatically a magnetic resonance imaging system according to the invention, and

Fig. 2 shows graphically a sequence of RF pulses and gradient pulses used to carry out the invention.

Fig. 1 shows diagrammatically a magnetic resonance imaging system in which the invention is used. The magnetic resonance imaging system includes a set of main coils for generating the steady, uniform magnetic field. The main coils are constructed, for example, in such a manner that they enclose a tunnel-like examination space. The patient to be examined is slid into said tunnel-like examination space. Furthermore, the magnetic resonance imaging system includes a number of gradient coils 11, 12 whereby spatially varying magnetic fields, notably in the form of temporary gradients in different directions, are superposed on the uniform magnetic field. The gradient coils 11, 12 are connected to a variable power supply unit 21. The gradient coils 11, 12 are energized by applying an electrical current thereto by means of the power supply unit 21. The strength, the direction